

Exploring the Role of Anti-Oxidant on Growth and Yield of Cotton to Mitigate the Heat Stress

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Agriculture experiencing a continuous pressure of food in order to meet the necessities of rising population. The cottonseed used as oilseed as well as a major source of edible oil in Pakistan. Cotton production affected by biotic and abiotic factors. Experiment was done at Central Cotton Research Institute, Multan in 2019 to study the effect of foliar application of gibberellic acid (GA), ascorbic acid (AA), citric acid (CA) and a control group in which no antioxidant was used against heat stress. Design used for experiment was randomized complete block design (RCBD). In trial cultivar of cotton CIM-610 was used. Experiment was replicated four times. Plot size was 9m (length) x 6m (width) with net plot size of 54 m². Statistically significant results among the morphological plus physiological attributes were observed. Almost yield parameters as plant height, nodes per plant buds per plant and bolls per plant have maximum values every month from May to October, sympodial branches (39), boll weight (2.97g), seed cotton yield (3097 kg), ginning out turn (39.133), fiber length (27.33 mm), fiber strength (28.8g tex), 100 seed weight (8.363g), fiber brightness (68.97Rd), micronaire (5.5) and uniformity index (83.48%) were leading in exogenous application of GA then AA, thirdly application of CA. In GA treatment maximum of plant height, bolls per plant, boll weight, monopodial branches and seed cotton yield were seemed. Seed cotton and lint quality yield reduced greatly due to heat stress. Antioxidants application of exogenous can sustain cotton yield and quality against heat stress conditions. Antioxidants of plants gave best results than where no treatment was applied.

Keywords: Cotton, gibberellic acid, citric acid, acetic acid, anti-oxidant, exogenous.

INTRODUCTION

Cotton is a basic fiber crop and source of vegetable oil. Cotton (*Gossypium hirsutum* L.) is also known as “White Gold” throughout world. By products which obtained from cotton crop are given as. Primary product is lint. Secondly, the cotton seed left after ginning (Shuli *et al.*, 2018). The third one is oil-cake (Ferro *et al.*, 2020). Drought is a major stress which reduce the cotton yield and create the conditions which effect the yield. The major changes create in cotton crop due to high temperature included deep roots development, close of

stomata, cellular changes, photosynthesis, production of abasic acid and jasmonic acid and reactive oxygen species (ROS) scavenging, have been find by scientist (Ullah *et al.*, 2017). High temperature and heat stress is a considerable issue which cause reduction in yield of cotton (*Gossypium hisutum* L.). More temperature negatively effect on viability of pollens un-fertilization in anther, which cause yield losses. In cotton pollen development, pollen tube growth and fertilization are postulated the heat-sensitive stages of the reproductive growth phase (Zinn *et al.*, 2010). Cotton plant have

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the ability combat under adverse climatic conditions by production of various chemicals is a major reason. (Zahid *et al.*, 2016).

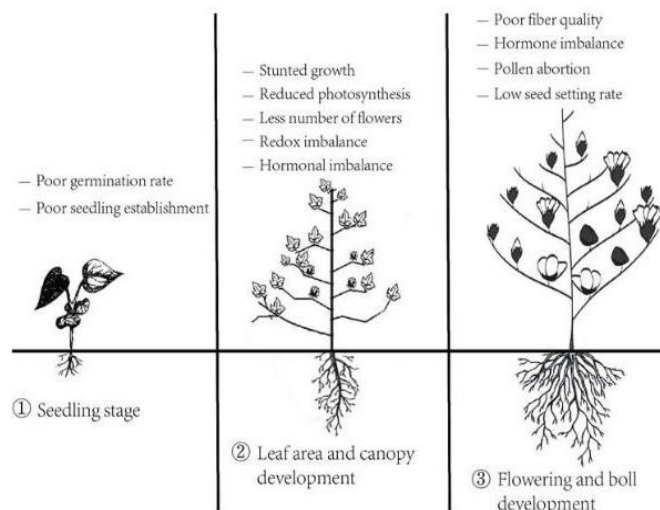


Figure 1. Effect of rise excessive temperature on agronomic and physiological attributes of cotton at different developmental stages (Constable and Bange, 2015).

Main reason of low yield in wheat crop production is the farmer unawareness about the importance of micronutrients for crop production (Nazeer *et al.*, 2020). Sometimes application of antioxidants from outside to crops to reduce the effect of various abiotic stress positively. Anti-oxidant enzymes useful for screening to find out the tolerant plus sensitive genotypes of plant against abiotic stresses (Kusvuran and Dasgan, 2017). Plants produce different types of organic acids having naturally anti-oxidant activities like gibberellic acid ascorbic acid etc. Plants under high temperature cause production of un-folded proteins in endoplasmic reticulum that resulted un-folded protein response which is a major response under heat stress (Schröder and Kaufman, 2005). High amount of antioxidant which are naturally present in plants is Ascorbic acid. It also help to regulate cell division, regulation of stomata, cell enlargement and floral induction (Barth *et al.*, 2006). Studies indicate that foliar applied ascorbic acid (40mgL^{-1}) reduce the injury of cell and enhance yield associated components under various intensities of heat (Kamal *et al.*, 2017).

Exogenous applied gibberellin not only increase the fiber length of cotton but also enhance thickness of cell wall. By the presence of abiotic stress the length of cotton fiber increase as well as thickness (Hassan, 2020). By application of citric acid the membrane stability, root activity and activation of antioxidant responses obtained (Hu *et al.*, 2016). The effectiveness of antioxidants in mitigating heat stress in cotton very small work has been found on it. To mitigate all these facts, this research trial has been conducted to achieve

the following objectives: the role of antioxidants to enhance growth and morphological factors of plant growth, to determine the role of application of antioxidants to mitigate heat stress in cotton, to investigate the yield components of cotton varieties as effected by application of antioxidant.

MATERIALS AND METHODS

Trail was conducted to investigate the good anti-oxidants (GA, AA and CA) to minimize the effect of heat stress in cotton. Cotton crop effected by heat stress due to high temperature which may rise upto 52°C in Multan. Soil samples are collected from experimental site by soil augur. Collect the samples from the depth of 0-30cm. Mix collected samples to form a composite sample and then packed them in plastic bag for analysis. The soil condition of the experimental site is given in Table 1.

Table 1. Physical and chemical analysis of soil samples taken from experimental site.

Soil Characteristics	Unit	Soil Dept	
		0-15 cm	16-30 cm
Sand	%	17	20
Silt	%	58	56
Clay	%	25	24
Textural class	Nil	Silt loam	Silt loam
pH	Nil	7.90	7.60
EC	dsm^{-1}	2.69	2.65
Nitrogen (N)	mgkg^{-1}	5.31	4.92
Phosphorous (P)	mgkg^{-1}	9.20	8.96
Potassium (K)	mgkg^{-1}	124	121
Organic matter (OM)	%	0.87	0.83

Soil Dept

Analysis of soil particles: For soil particles analysis Bouyoucos method was adopted. For this 1% of sodium hexa meta-phosphate add up for solution dispersion. For 50g soil sample, 1% sodium hexa meta-phosphate along with distilled water was used to nightly soak. Electric stirrer to stir solution. Solution moved to graduated cylinder with volume of 1 liter.

Determination of soil texture: Bouyoucos method practiced for soil texture determination. 1% of sodium hexa-metaphosphate attained as dispersing agent for 50g soil sample. For 1% solution of dispersing agent along with distilled water of 50g soil, leave it whole night. Stir the solution then poured in graduated cylinder. After an hour separate layers of sand, silt and clay can be observed.

Soil saturation (%): Need 50g of saturated soil paste for determination of soil saturation %, place it in dish. Then weight it and dried at 105°C in oven and weight it again. Saturation % of soil calculated by using the mentioned formula:



Soil saturation (%) = Mass of wet-soil – mass of dried-soil
Soil's pH determination: From experimental site 200g soil was taken then saturate it with the use of distilled water then pH value was determined by using pH meter.

Soil EC determination: Digital conductivity device 4070 used for soil EC.

Organic matter (%) of soil: For this 5g of soil mixed with conc. H₂SO₄ (150 ml) and potassium dichromate (10 ml) completely. Then ferrrous-sulphate (25 mL of 0.1 N) was used in soil solution.

Soil nitrogen: Kjeldhal's apparatus used to determine nitrogen in soil sample. 10g soil with 40ml conc. H₂SO₄ was mixed along with digestion mixture of 10g. Distillation done with the help of Kjeldhal's apparatus. In this method NH₃ absorbed. Whole material titrated against 0.1N H₂SO₄. Nitrogen form sample was determined by using the formula: Nitrogen (%) = 0.0014 × (volume of acid use for titration) × dilution factor × 100 ml sample.

Determination of soil phosphorus: Soil sample as 10g extracted along 0.5 M NaHCO₃. pH adjusted as 8.5 after extraction, aliquot 5 ml added in 100 ml volumetric flask. For coloration, ascorbic acid as 5 ml added in flask. By adding distilled water, 100ml of the solution mixture was achieved. Mixture of solution was run on spectro-photometer. Results were recorded at 880nm wavelength.

Soil potassium: In extraction tube soil sample of 10g was taken. For extraction of soil potassium, 0.145 M of ammonium acetate was adopted as agent.

Field was ploughed after harvesting previous crop to mix plant residues with soil. Again field was ploughed four times with chisel plus rotavator in order to pulverize soil and levelling soil. Bed ridger used for beds. Delinted seed of 6-7 kg was used per acre. For this trail in filed bed-furrow method was adopted. Hand dibbling method was adopted for seed sown and 2-3 seeds were dropped per hill. Plots dimensions was 2.5 feet Row-Row (30 inches) and 0.75 feet Plant-Plant (9 inches). At maturity two picking picked with 40 days interval. Both picking's data combined to calculated seed cotton yield. Collected data analyzed by using software, Statistix 8.1. Analysis of variance was compared by LSD test at 5% level of significance (Steel *et al.*, 1997).

RESULTS AND DISCUSSIONS

Agronomic parameters plant height (cm): The highest plant height showed in (Table 2) obtained in GA treatment, 28.87 (cm) in May until 149.25 (cm) in the October than remaining factors done under same scenarios followed by AA and CA. Minimum growth was recorded in control which was 27.45 (cm) in May and 122.15 (cm) was in October. The present consequence are same with previous research observed for this parameter in flax to gibberellic acid (Rastogi *et al.*, 2013). CA enhances plant growth, Studies investigated that

citric acid application promotes root plus shoot length under stress conditions (Mallhi *et al.*, 2019).

Nodes per plant: Highest nodes per plant (Table 2) was recorded with the use of GA very month as it yield 9.525 nodes in month of May and enhance moderately to 33.5 nodes in the month October than remaining treatments. The minimum nodes numbers per plant was obtained as 9.025 nodes in May then 27.3 nodes till October. Present result in line with previous research that the use of growth regulators and reducers effect the nodes number during cotton growth (Yasmeen *et al.*, 2016). While it observed that GA use in cotton plant highly increase number of nodes of cotton (Copur *et al.*, 2019).

Buds per plant: The maximum buds per plant (Table 2) was obtained from treatment where we applied GA which was 5 buds per plant in May enhanced to 12.25 buds per plant in month of October. While minimum buds per plant were calculated from with 5 buds in May to 8.65 buds till October. GA positively effect on vegetative growth of of cotton plant and reduce heat stress (Copur *et al.*, 2019). Likewise, citric acid also reduce the effect of heat and improve process of plant growth (Hu *et al.*, 2016).

Bolls per plant: The highest numbers of boll per plant (Table 2) was obtained from treatment of GA, each month 5.1 in June until 32 in month of October compared remaining applications applied under same scenarios. Minimum number of whole bolls was calculated from control which is 3.9 in June till 22 in October. Number of bolls per plant directly relate with heat stress, boll splition is affected by the fundamental atmosphere temperature. Plant growth regulators spray enhanced the boll formation process and boll opening resulting in higher boll weight and size in cotton (Shakoor *et al.* 2017). Application of GA positively effect on plant growth (Çopur *et al.*, 2010).

Sympodial branches (plant⁻¹): The highest value of sympodial branches (Table 3) obtained where GA was applied 39 sympodial branches/plant. Minimum 31 sympodial branches per plant counted in control due to the heat stress. Previous studies indicated GA application enhanced number of sympodial branches (Copur *et al.*, 2019). Similarly, GA in flax also proceed to raise no. of branches (Rastogi *et al.*, 2013).

Monopodial branches: The result of number of monopodial branches nonsignificant. Shown in Table 3.

Boll weight (g): The maximum boll weight in Table 3 indicated that more yield of seed cotton and ultimately enhance productivity of cotton. The highest value of boll weight obtained where apply GA 2.97 (g) boll weight on an average fallowed by AA and CA application. Minimum boll weight noted from control 2.68 (g) due to the heat stress. Temperature stress negatively affect vegetative plus reproductive growth and also minimize boll weight (Fitzsimons, 2016). Application of GA at various growth stages of cotton crop enhance vegetative and reproductive



Table 2. Effect of anti-oxidant on agronomic parameters of cotton.

Month	Treatments	Plant height (cm)	Nodes per plant	Buds per plant	Bolls per plant
May	Gibberellic Acid (GA)	28.87a	9.52a	6.20a	
	Ascorbic Acid (AA)	27.80b	9.22b	5.80b	
	Citric Acid (CA)	27.50b	9.15b	5.60b	
	Control (C)	27.45b	9.02b	5.00b	
	LSD	1.04	0.24	0.17	
June	Gibberellic Acid (GA)	69.60a	25.10a	17.60a	5.10a
	Ascorbic Acid (AA)	68.50b	23.50b	16.60b	4.70b
	Citric Acid (CA)	66.70c	21.60c	15.40c	4.20c
	Control (C)	62.40d	20.30d	13.20d	3.90d
	LSD	1.04	1.01	0.79	0.24
July	Gibberellic Acid (GA)	108.20a	30.10a	17.90a	15.20a
	Ascorbic Acid (AA)	106.60ab	29.30ab	16.90b	14.50b
	Citric Acid (CA)	105.20b	27.50b	15.60b	13.90b
	Control (C)	101.40c	24.20c	13.80c	11.20c
	LSD	2.69	1.88	1.07	0.65
August	Gibberellic Acid (GA)	117.20a	32.00a	18.70a	17.00a
	Ascorbic Acid (AA)	115.40b	31.15ab	17.90a	16.00b
	Citric Acid (CA)	112.80c	30.15bc	16.60b	16.00b
	Control (C)	110.70d	29.65c	15.20c	13.00c
	LSD	1.68	1.00	0.99	1.12
September	Gibberellic Acid (GA)	120.20a	32.90a	15.50a	19.90a
	Ascorbic Acid (AA)	119.30a	31.20b	14.70b	18.70a
	Citric Acid (CA)	117.60b	30.90b	13.50c	17.20b
	Control (C)	115.20c	29.70c	12.90c	15.30c
	LSD	1.41	1.06	0.76	1.49
October	Gibberellic Acid (GA)	149.25a	33.50a	12.25a	32.00a
	Ascorbic Acid (AA)	135.25b	31.00b	10.95b	29.00ab
	Citric Acid (CA)	128.5bc	29.60b	10.70b	26.00bc
	Control (C)	122.15c	27.30c	8.65c	22.00c
	LSD	7.47	1.69	1.17	4.56

growth of cotton crop and diminish heat stress effect (Alonso-Ramírez *et al.*, 2009).

Seed cotton yield: The seed cotton yield indicate the overall yield of cotton and lint. The significant relation was found between them in Table 3. The highest value of seed cotton was calculated from where we apply GA treatment which was found to be 3097 (kg). Minimum obtained from control where we simply apply distilled water seed cotton yield was recorded as 2115 (kg). High temperature reduce the cotton yield and effect the plants ability (Zafar *et al.*, 2018). High temperature directly affect the agronomic characteristics of cotton plant which involve in yield related traits (Ekinici *et al.*, 2017).

Ginning out turn (%): Cotton yield is determine through ginning out turn. The present result indicate that the highest value of ginning out turn (39.133%) was observed in consequence to exogenous usage of GA in Table 3. While minimum 36.984% was recorded for control experiment. Ginning out turn loss because of heat stress and fiber development not happen accordingly (Zafar *et al.*, 2018). GA

increase cotton fiber, while CA improve effects of different stresses (Copur *et al.*, 2019; Mallhi *et al.*, 2019).

Fiber length (mm): The significant variation was obtained in fiber length (Table 3). The highest fiber length was obtained from treatment where we apply GA as recorded 27.33 mm. while minimum are recorded from control is 25.48 mm, due to various reason major is due to heat stress. Outcomes recorded for AA and CA application were statistically at par. High temperature negatively affect cotton yield, fiber length and other quality parameters (Zahid *et al.*, 2016). Application of GA during fiber development positively effect on the fiber length (Xiao *et al.*, 2010).

Fiber strength (g tex⁻¹): Fiber strength is a basic quality parameters of cotton crop. Maximum value of fiber strength parameter was obtained where GA apply 28.8 (g/tex) showed in Table 3. While minimum was as 25.65 (g/tex) from control. Outcomes investigated that secondly better seed cotton yield was observed under acetic acid application (Zahid *et al.*, 2016). Exogenous applied GA promote fiber length during fiber development (Xiao *et al.*, 2010).



Table 3. Effect of anti-oxidant on agronomic parameters of cotton.

Treatments	Sympodial branches	Monopodial branches	Boll weight (g)	Seed cotton yield (kg)	Ginning out turn	Fibre length (mm)	Fibre strength (g tex ⁻¹)	Fibre yellowness (+b)	Seed weight (100)	Fibre brightness (Rd)	Micro-naire (µg inch ⁻¹)	Uniformity index (%)
Gibberellic acid (GA)	39A	1.9	2.97A	3097A	39.13A	27.33A	28.80A	6.95D	8.36A	68.98A	5.5A	83.48A
Ascorbic acid (AA)	38A	1.8	2.85B	2784B	38.15AB	26.68AB	27.82B	7.20C	7.42AB	68.38B	5.1B	82.48B
Citric acid (CA)	34B	1.7	2.85B	2560C	37.16BC	25.93BC	26.65C	7.58B	7.37B	67.55B	4.9BC	82.30B
Control (C)	31C	1.6	2.68C	2115D	36.95C	25.48C	25.65D	7.95A	6.92B	66.55C	4.7C	80.68C
LSD(p≤0.05)	2.46	0.33	0.10	134.10	1.03	1.14	0.62	0.22	0.97	0.54	0.28	0.75

Mean sharing unlike letters for the effect differs significantly at $P \leq 0.05$

Fiber yellowness (+b): Yellowness of fiber is not desired in industries. Highest yellowness of cotton fiber showed in Table 3 was calculated from control that is 7.95, as it may be due to more temperature. Minimum fiber yellowness 6.95. Yellowness in fiber is develop due to various factors it may be due to abiotic stress (Bischof *et al.*, 2011).

Seed weight (100): The maximum seed weight of cotton crop obtained from treatment where we apply GA seed weight 8.363 (g) of 100 seeds showed in Table 3. Minimum value of 100 seed weight which is calculated from control is 6.925 (g). Seed weight and size is directly related with biotic and abiotic factors during high temperature reduce seed weight (Fitzsimons, 2016). So by the application of GA reduce the heat effect and increase seed weight (Copur *et al.*, 2019).

Fiber brightness (Rd): Fiber brightness is important quality parameter of cotton crop. Highest fiber brightness was 68.975 (Rd) where we apply GA. Least value 66.55 (Rd) for fiber brightness was calculated from control showed in Table 3. As other parameters adversely effected by abiotic stress fiber brightness also inversely effect (Abdel-Kader *et al.*, 2015). GA positively effect on fiber brightness due to reducing the effect of heat stress (Alonso-Ramírez *et al.*, 2009).

Micronaire (µg inch⁻¹): The formula used to calculate micronaire is micronaire value = maturity × fineness. Maximum micronaire (Table 3) was obtained from treatment where we apply GA 5.5 (µg/inch). Minimum value calculated from control which is 4.7 (µg/inch). From control we get minimum micronaire due to more heat stress (Zahid *et al.*, 2016) and by the application of GA reduce the heat effect and enhance the quantity of micronaire (Xiao *et al.*, 2010).

Uniformity index (%): Highest fiber uniformity index was 83.48 (%) obtained where we apply GA. While Minimum value 80.68 (%) were obtained from control (Table 3) where

we not apply any treatment and apply simple distilled water. By the application of antioxidant like GA increase the uniformity index of fiber (Copur *et al.*, 2019; Huang *et al.*, 2015; Xiao *et al.*, 2010).

Physiological Parameters: Days taken to 1st bud, Minimum days require to appear first bud is 39.5 days due to application of GA. Maximum days require to initiate first bud in cotton crop is 43.25 days (Table 4). GA permote vegetative growth as well as reproductive growth that's why less days require to initiate first bud where apply GA (Huang *et al.*, 2015).

Days taken to 1st flower: Minimum days in which first flower initiate is 61 days where we apply GA as compare to other treatments can be seemed in Table 4. Maximum days require to initiate first flower on plants of 65 days. At high temperature due to heat stress the plant growth retard (Shakoor *et al.* 2017). As discusses previous the application of GA reduce the effect of heat stress (Xiao *et al.*, 2010; Zhang *et al.*, 2017).

First sympodial node number: Highest number of first sympodial nodes was recorded as 6.88 in GA treatment fallowed by AA and CA. while minimum number was noted from control which are 5.93 showed in Table 4. GA application increase the growth of plant and increase the number of sympodial branches (Huang *et al.*, 2015).

First sympodial node height (cm): Data was observed as significant for 1st sympodial node height (Table 4). Maximum value of 21.5 (cm) was observed in gibberellic acid. In control less value of 17.5 (cm) gained. Because during more temperature, cotton plant's growth stunted (Shakoor *et al.* 2017). GA used to enhance growth in unfavorable climatic conditions as physiological performance optimized for the suitable growth (Xiao *et al.*, 2010; Zhang *et al.*, 2017).

Table 4. Effect of anti-oxidant on physiological parameters of cotton.

Treatments	Days taken to first bud	Days taken to first flower	First sympodial node number	First sympodial node length	Sympodial node no. bearing 1 st boll	Sympodial node height bearing first boll (cm)	Boll set on 1 st position	Boll set on 2 nd position	Days to 1 st sp
Gibberellic acid (GA)	39.50A	61.0C	6.88A	21.5A	8.00A	24.23A	27.00A	21.75A	95.0
Ascorbic acid (AA)	40.75A	62.5BC	6.70AB	20.0AB	6.88B	21.15B	20.65B	14.70B	96.0
Citric acid (CA)	42.25B	63.5AB	6.10BC	18.7BC	6.80B	20.98B	15.35C	12.00BC	97.0
Control (C)	43.25C	65.0A	5.93C	17.5C	6.32B	18.63B	14.60C	11.30C	98.0
p≤0.05)	1.13	2.16	0.67	1.88	0.84	2.71	2.05	1.99	1.3

Mean sharing unalike letters for the effect differs significantly at $P \leq 0.05$



Sympodial node number bearing 1st boll: Highest number of sympodial nodes was recorded was 8 from treatment where apply GA (Table 4). Minimum value was 6.325 which were obtained from control. High temperature reduce the growth and physiological traits of cotton crop (Zahid *et al.*, 2016). Foliar applied growth regulators of plant significantly promotes growth of cotton against the abiotic stresses (Yasmeen *et al.*, 2016).

Sympodial node height bearing 1st boll (cm): Highest value for this parameter was 24.23 (cm) recorded from treatment where we apply GA. While minimum 18.63 (cm) was obtained from control (Table 4). GA at different growth stages increases growth to alleviate the heat stress (Alonso-Ramírez *et al.*, 2009).

Boll set on 1st position: Highest value was calculated from treatment of GA (Table 4) where boll weight set in 1st place gained as 27 (g). Minimum value was gained from control where boll weight set on 1st point was observed as 14.6 (g). Acetic acid was studied as antioxidant in various plants to promote tolerance in plants against numerous stresses like abiotic (Alayafi, A.A.M., 2020).

Boll set on 2nd position: Data recorded weight of boll set on 2nd position was significant (Table 4). Best outputs were gained from the treatment of GA for which boll weight set in 2nd position was observed as 21.75 (g). Less preferable outcomes were gained from control where boll weight set on 2nd place was observed as 11.3 (g). Secondly good outcomes were seemed in AA treatment where boll weight set on 2nd position was as 14.7 (g). In Pakistan, more temperature during months of July and August badly affect no. of seed/boll and lowered cotton boll size (Zahid *et al.*, 2016). While investigated that in cotton plant GA promote no. of nodes and boll setting position (Copur *et al.*, 2019).

Days taken to first boll split: Significant data was observed for number of days taken to 1st boll split (Table 4). Least days taken for 1st boll split was as 95 days. In control, more days observed for first boll to split an average of as 98 days. To split first boll in AA 96 days were taken. The process of splitting of boll in cotton cause yield loss due to heat stress. As temperature raised gradually, boll split boosted with premature boll opening which results in serious decline in seed cotton yield (Ekinici *et al.*, 2017).

Conclusion: The study shows that during summer, temperature goes beyond 45 degree centigrade which ultimately reduces the yield of cotton crop and also its quality of fiber as well as oil contents. By using exogenous application of antioxidants on cotton can reduce the heat stress to great extent. Among antioxidants GA application enhances cotton productivity against heat stress

Conflict of interest: No conflict of interest is declared by authors

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REFERENCES

- Abdel-Kader, M.A., A.M. Esmail, K.A. El Shouny and M.F. Ahmed. 2015. Evaluation of the drought stress effects on cotton genotypes by using physiological and morphological traits. *International Journal of Science and Research* 4:1358-1366.
- Alayafi, A.A.M. 2020. Exogenous ascorbic acid induces systemic heat stress tolerance in tomato seedlings: transcriptional regulation mechanism. *Environmental Science and Pollution Research* 27:19186-19199.
- Alonso-Ramírez, A., D. Rodríguez, D. Reyes, J.A. Jiménez, G. Nicolás, M. López-Climent, A. Gómez-Cadenas and C. Nicolás. 2009. Evidence for a role of gibberellins in salicylic acid-modulated early plant responses to abiotic stress in Arabidopsis seeds. *Plant Physiology* 150:1335-1344.
- Barth, C., M. De Tullio and P.L. Conklin. 2006. The role of ascorbic acid in the control of flowering time and the onset of senescence. *Journal of experimental botany* 57:1657-1665.
- Bischof Vukušić, S., S. Flinčec Grgac, A. Budimir and S. Kalenić. 2011. Cotton textiles modified with citric acid as efficient antibacterial agent for prevention of nosocomial infections. *Croatian medical journal* 52:68-75.
- Constable, G.A. and M.P. Bange. 2015. The yield potential of cotton (*Gossypium hirsutum* L.). *Field Crops Research* 182:98-106.
- Copur, O., T. Demirel and C. Odabaşioğlu. 2019. Effect of different gibberellic acid doses and application times on cotton (*Gossypium hirsutum* L.) in southeastern Anatolia region of turkey. *Applied Ecology and Environmental Research* 17:14985-14999.
- Copur, O., U. Demirel and M. KARAKUŞ. 2010. Effects of several plant growth regulators on the yield and fiber quality of cotton (*Gossypium hirsutum* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 38:104-110.



- Ekinci, R., S. Başbağ, E. Karademir and C. Karademir. 2017. The effects of high temperature stress on some agronomic characters in cotton.
- Ferro, M.M., A. De Moura Zanine, A.L. De Souza, D. De Jesus Ferreira, E.M. Santos, G. Ribeiro Alves, L.J. Valério Geron and R.M. Araujo Pinho. 2020. Residue from common bean in substitution of cottonseed cake in diets for sheep. *Biological Rhythm Research* 51:471-480.
- Fitzsimons, T.R., 2016. Heat stress effects on cotton during reproductive development and subsequent acclimation responses.
- Hassan, A., M. Ijaz, A. Sattar, A. Sher, I. Rasheed, M.Z. Saleem and I. Hussain 2020. Abiotic stress tolerance in cotton. *Advances in cotton research*.
- Hu, L., Z. Zhang, Z. Xiang and Z. Yang. 2016. Exogenous application of citric acid ameliorates the adverse effect of heat stress in tall fescue (*Lolium arundinaceum*). *Frontiers in plant sci.*, 7, p.179.
- Huang, D., S. Wang, B. Zhang, K. Shang-Guan, Y. Shi, D. Zhang, X. Liu, K. Wu, Z. Xu, X. Fu and Y. Zhou 2015. A gibberellin-mediated DELLA-NAC signaling cascade regulates cellulose synthesis in rice. *The Plant Cell*:1681-1696.
- Kamal, M.A., M.F. Saleem, M.A. Wahid and A. Shakeel. 2017. EFFECTS OF ASCORBIC ACID ON MEMBRANE STABILITY AND YIELD OF HEATSTRESSED BT COTTON. *JAPS: Journal of Animal & Plant Sciences* 27:1-7.
- Kusvuran, S. and H.Y. Dasgan. 2017. Drought induced physiological and biochemical responses in *Solanum lycopersicum* genotypes differing to tolerance. *Acta scientiarum polonorum hortorum cultus* 16:19-27.
- Mallhi, Z.I., M. Rizwan, A. Mansha, Q. Ali, S. Asim, S. Ali, A. Hussain, S.H. Alrokayan, H.A. Khan, P. Alam and P. Ahmad. 2019. Citric acid enhances plant growth, photosynthesis, and phytoextraction of lead by alleviating the oxidative stress in castor beans. *Plants* 8: 525.
- Nazeer, S., M. Tahir, M. Sajjad, M. Idrees, M.A. Saleem, A. Shehzad and M.U. Hameed. 2020. Response of Different Micronutrients (Zn, Cu and Mn) Soil Application on Yield and Quality of Late Sown Wheat (*Triticum aestivum* L.) under Faisalabad Conditions Pakistan *Journal of Life and Social Sciences* 18:65-70
- Rastogi, A., A. Siddiqui, B.K. Mishra, M. Srivastava, R. Pandey, P. Misra, M. Singh and S. Shukla 2013. Efeito da auxina e do ácido giberélico no crescimento e nos componentes de produção de linhaça (*Linum usitatissimum* L.). *Crop Breeding and Applied Biotechnology* 13:136-143.
- Schröder, M. and R.J. Kaufman. 2005. The mammalian unfolded protein response. *Annu. Review Biochem* 74:739-789.
- Shakoor, A., M.F. Saleem, S.A. Anjum, M.A. Wahid and M.T. Saeed. 2017. Effect of heat stress and benzoic acid as foliar application on earliness and nutrients uptake in cotton. *J. of Agric. Res.* (03681157), 55(1).
- Shuli, F., A.H. Jarwar, X. Wang, L. Wang and Q. Ma. 2018. Overview of the cotton in Pakistan and its future prospects. *Pakistan Journal of Agricultural Research* 31:396.
- Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics. A biometrical approach. 2nd Edition. McGraw Hill, Inc. USA.
- Ullah, A., H. Sun, X. Yang and X. Zhang. 2017. Drought coping strategies in cotton: increased crop per drop. *Plant biotechnology journal* 15:271-284.
- Xiao, Y.H., D.M. Li, M.H. Yin, X.B. Li, M. Zhang, Y.J. Wang, J. Dong, J. Zhao, M. Luo, X.Y. Luo and L. Hou, 2010. Gibberellin 20-oxidase promotes initiation and elongation of cotton fibers by regulating gibberellin synthesis. *Journal of plant physiology* 167:829-837.
- Yasmeen, A., M. Arif, N. Hussain, W. Malik and I. Qadir. 2016. Morphological, Growth and Yield Response of Cotton to Exogenous Application of Natural Growth Promoter and Synthetic Growth Retardant. *International Journal of Agric. & Biology*, 18(6).
- Zafar, S.A., M.A. Noor, M.A. Waqas, X. Wang, T. Shaheen, M. Raza and M.U. Rahman. 2018. Temperature Extremes in Cotton Production and Mitigation Strategies. Past, Present and Future Trends in Cotton Breeding, May 2018. <https://doi.org/10.5772/intechopen.7464>
- Zahid, K.R., F. Ali, F. Shah, M. Younas, T. Shah, D. Shahwar, W. Hassan, Z. Ahmad, C. Qi, Y. Lu and A. Iqbal. 2016. Response and tolerance mechanism of cotton *Gossypium hirsutum* L. to elevated temperature stress: a review. *Frontiers in plant science* 7:937.
- Zhang, Y., P. He, Z. Yang, G. Huang, L. Wang, C. Pang, H. Xiao, P. Zhao, J. Yu and G. Xiao. 2017. A genome-scale analysis of the PIN gene family reveals its functions in cotton fiber development. *Frontiers in plant sciences* pp.461.
- Zinn, K.E., M. Tunc-Ozdemir and J.F. Harper. 2010. Temperature stress and plant sexual reproduction: uncovering the weakest links. *Journal of experimental botany* 61:1959-1968.

